

What is claimed is:

1        1. A three-dimensional optical cross-connect switch, the switch comprising:  
2            a first optical switching array including a first tile disposed in a first plane and a  
3            second tile aligned plane-to-plane with the first tile in a second plane, the first tile including a  
4            first collimator array disposed adjacent to a first beam steering array and the second tile  
5            including a second collimator array disposed adjacent to a second beam steering array, the  
6            first optical switching array being characterized by a first array maximum deflection angle;  
7            and

8            a second optical switching array including a third tile disposed in the first plane and a  
9            fourth tile aligned plane-to-plane with the third tile in the second plane, the third tile  
10           including a third collimator array disposed adjacent to a third beam steering array, and the  
11           fourth tile including a fourth collimator array disposed adjacent to a fourth beam steering  
12           array, whereby a switch maximum deflection angle is less than or equal to the first array  
13           maximum deflection angle.

1        2. The switch of claim 1, wherein the first collimator array, the third collimator array,  
2           the first beam steering array, and the third beam steering array are arranged in a  
3           checker-board pattern.

1        3. The switch of claim 1, wherein the second collimator array, the fourth collimator  
2           array, the second beam steering array, and the fourth beam steering array are arranged in a  
3           checker-board pattern.

1        4. The switch of claim 1 wherein the second optical switching array is characterized  
2           by a second array maximum deflection angle.

1        5. The switch of claim 4, wherein the switch maximum deflection angle is less than or  
2           equal to the second array maximum deflection angle.

1        6. The switch of claim 4, wherein the first array maximum deflection angle is equal to  
2    the second array maximum deflection angle.

1        7. The switch of claim 1, wherein each of the first beam steering array, the second  
2    beam steering array, the third beam steering array, and the fourth beam steering array include  
3    at least one beam steering pixel.

1        8. The switch of claim 7, wherein the at least one beam steering panel includes an  $N \times$   
2     $N$  array of beam steering pixels.

1        9. The switch of claim 8, further comprising a control system coupled to the beam  
2    steering panel, the control system being configured to provide a control signal to each pixel  
3    in the  $N \times N$  array of beam steering pixels.

1        10. The switch of claim 7, wherein the at least one beam steering pixel includes a  
2    MEMS mirror element.

1        11. The switch of claim 7, wherein the at least one beam steering pixel includes a  
2    gimbaled MEMS mirror element having at least two-degrees of beam steering freedom.

1        12. The switch of claim 7, wherein the at least one beam steering pixel includes a  
2    plurality of individually steerable mirror elements.

1        13. The switch of claim 12, further comprising a control system coupled to the beam  
2    steering panel, the control system being configured to provide a control signal to each of the  
3    individually steerable mirror elements.

1        14. The switch of claim 7, wherein each of the first collimator array, the second  
2    collimator array, the third collimator array, and the fourth collimator array include at least

3 one collimator coupled to an optical fiber.

1 15. The switch of claim 14, wherein the at least one collimator panel includes an  $N \times$   
2  $N$  array of collimators.

1 16. The switch of claim 1, wherein the switch is characterized by a  $z/d$  ratio greater  
2 than ten (10),  $z$  being a distance between the first plane and the second plane, and  $d$  being a  
3 width of a beam steering array.

1 17. A three-dimensional optical cross-connect switch, the switch comprising:  
2 a first optical switching array including a first tile having a first collimator array disposed  
3 adjacent to a first beam steering array and a second tile having a second collimator array  
4 disposed adjacent to a second beam steering array, the second collimator array being aligned  
5 plane-to-plane with the first beam steering array and the second beam steering array being  
6 aligned plane-to-plane with the first collimator array; and  
7 a second optical switching array including a third tile having a third collimator array disposed  
8 adjacent to a third beam steering array, and a fourth tile having a fourth collimator array  
9 disposed adjacent to a fourth beam steering array, the fourth collimator array being aligned  
10 plane-to-plane with the third beam steering array and the fourth beam steering array being  
11 aligned plane-to-plane with the third collimator array, whereby the third beam steering array  
12 is disposed adjacent the first collimator array.

1 18. The switch of claim 17, wherein the first collimator array, the third collimator  
2 array, the first beam steering array, and the third beam steering array are arranged in a  
3 checker-board pattern.

1 19. The switch of claim 17, wherein the second collimator array, the fourth collimator  
2 array, the second beam steering array, and the fourth beam steering array are arranged in a  
3 checker-board pattern.

1        20. The switch of claim 17, wherein the second optical switching array is  
2 characterized by a second array maximum deflection angle.

3  
4        21. The switch of claim 20, wherein the switch maximum deflection angle is less than  
5 or equal to the second array maximum deflection angle.

1        22. The switch of claim 20, wherein the first array maximum deflection angle is equal  
2 to the second array maximum deflection angle.

1        23. The switch of claim 17, wherein the switch is characterized by a z/d ratio greater  
2 than ten (10), z being a distance between the first plane and the second plane, and d being a  
3 width of a beam steering array.

1        24. The switch of claim 17, wherein each of the first beam steering array, the second  
2 beam steering array, the third beam steering array, and the fourth beam steering array include  
3 at least one beam steering pixel.

1        25. The switch of claim 25, wherein the at least one beam steering panel includes an  
2 N x N array of beam steering pixels.

1        26. The switch of claim 25, wherein the at least one beam steering pixel includes a  
2 MEMS mirror element.

1        27. The switch of claim 25, wherein the at least one beam steering pixel includes a  
2 gimbaled MEMS mirror element having at least two-degrees of beam steering freedom.

1        28. A three-dimensional optical cross-connect switch, the switch comprising:  
2 a first optical switching array including a first tile disposed in a first plane and a second tile

3 disposed in a second plane parallel to the first plane, the first tile including a first collimator  
4 array disposed adjacent to a first beam steering array, the second tile having a second  
5 collimator array disposed adjacent to a second beam steering array, the first beam steering  
6 array and the second beam steering array each having N-steerable pixel elements, the first  
7 optical switching array being characterized by an array maximum deflection angle required to  
8 access each pixel in the first optical switching array; and  
9 a second optical switching array coupled to the first optical switching array, the second  
10 optical switching array including a third tile disposed in the first plane and a fourth tile  
11 disposed in the second plane, the third tile including a third collimator array disposed  
12 adjacent to a third beam steering array, the fourth tile including a fourth collimator array  
13 disposed adjacent to a fourth beam steering array, the third beam steering array and the fourth  
14 beam steering array each having N-steerable pixel elements, whereby a switch maximum  
15 deflection angle required to access each pixel in the cross-connect switch is less than or equal  
16 to the first array maximum deflection angle.

1           29. The switch of claim 29, wherein the first collimator array, the third collimator  
2 array, the first beam steering array, and the third beam steering array are arranged in a  
3 checker-board pattern.

1           30. The switch of claim 29, wherein the second collimator array, the fourth collimator  
2 array, the second beam steering array, and the fourth beam steering array are arranged in a  
3 checker-board pattern.

1           31. The switch of claim 29, wherein the second optical switching array is  
2 characterized by a second array maximum deflection angle.

1           32. The switch of claim 32, wherein the switch maximum deflection angle is less than  
2 or equal to the second array maximum deflection angle.

1        33. The switch of claim 32, wherein the first array maximum deflection angle is  
2        equal to the second array maximum deflection angle.

1        34. The switch of claim 29, wherein the switch is characterized by a z/d ratio  
2        greater than ten (10), z being a distance between the first plane and the second plane, and  
3        d being a width of a beam steering array.

1        35. The switch of claim 29, wherein each of the first beam steering array, the  
2        second beam steering array, the third beam steering array, and the fourth beam steering  
3        array include at least one beam steering pixel.

1        36. The switch of claim 36, wherein the at least one beam steering panel includes  
2        an N x N array of beam steering pixels.

1        37. The switch of claim 36, wherein the at least one beam steering pixel includes a  
2        MEMS mirror element.

1        38. The switch of claim 36, wherein the at least one beam steering pixel includes a  
2        gimbaled MEMS mirror element having at least two-degrees of beam steering freedom.

1        39. A method for expanding a switching capacity of a three-dimensional optical  
2        cross-connect switch, the method comprising:  
3        providing a first optical switching array including a first tile disposed in a first plane and a  
4        second tile aligned plane-to-plane with the first tile in a second plane, the first tile  
5        including a first collimator array disposed adjacent to a first beam steering array and the  
6        second tile including a second collimator array disposed adjacent to a second beam  
7        steering array, the first optical switching array being characterized by an array maximum  
8        deflection angle;  
9        providing a second optical switching array including a third tile disposed in the  
10      first plane and a fourth tile aligned plane-to-plane with the third tile in the second plane,  
11      the third tile including a third collimator array disposed adjacent to a third beam steering

12 array, and the fourth tile including a fourth collimator array disposed adjacent to the  
13 fourth beam steering array; and

14 coupling the first optical switching array to the second optical switching array,  
15 whereby a maximum deflection angle of the three-dimensional optical cross-connect  
16 switch is less than or equal to the array maximum deflection angle.

1 40. The method of claim 40, wherein the first collimator array, the third collimator  
2 array, the first beam steering array, and the third beam steering array are arranged in a  
3 checker-board pattern.

1 41. The method of claim 40, wherein the second collimator array, the fourth  
2 collimator array, the second beam steering array, and the fourth beam steering array are  
3 arranged in a checker-board pattern.

1 42. The method of claim 40, wherein the second optical switching array is  
2 characterized by a second array maximum deflection angle.

1 43. The method of claim 44, wherein the method maximum deflection angle is  
2 less than or equal to the second array maximum deflection angle.

1 44. The method of claim 44, wherein the first array maximum deflection angle is  
2 equal to the second array maximum deflection angle.

1 45. The method of claim 40, wherein the method is characterized by a z/d ratio  
2 greater than ten (10), z being a distance between the first plane and the second plane, and  
3 d being a width of a beam steering array.

1           46. A method for expanding a switching capacity of a three-dimensional optical  
2 cross-connect switch, the method comprising:  
3 providing a first optical switching array including a first tile having a first collimator  
4 array disposed adjacent to a first beam steering array and a second tile having a second  
5 collimator array disposed adjacent to a second beam steering array, the second collimator  
6 array being aligned plane-to-plane with the first beam steering array and the second beam  
7 steering array being aligned plane-to-plane with the first collimator array, the first optical  
8 switching array being characterized by a first array maximum deflection angle;  
9 providing a second optical switching array including a third tile having a third collimator  
10 array disposed adjacent to a third beam steering array, and a fourth tile having a fourth  
11 collimator array disposed adjacent to a fourth beam steering array, the fourth collimator  
12 array being aligned plane-to-plane with the third beam steering array and the fourth beam  
13 steering array being aligned plane-to-plane with the third collimator array, whereby the  
14 third beam steering array is disposed adjacent the first collimator array; and  
15 coupling the first optical switching array to the second optical switching array, whereby a  
16 maximum deflection angle of the three-dimensional optical cross-connect switch is less  
17 than or equal to the array maximum deflection angle.

1           47. A method for switching optical signals in a three-dimensional optical  
2 cross-connect switch, the switch including a first optical switching array including a first  
3 tile disposed in a first plane and a second tile aligned plane-to-plane with the first tile in a  
4 second plane, the first tile including a first collimator array disposed adjacent to a first  
5 beam steering array and the second tile including a second collimator array disposed  
6 adjacent to a second beam steering array, the first optical switching array being  
7 characterized by an array maximum deflection angle, the method comprising:  
8           providing a second optical switching array including a third tile disposed in the  
9 first plane and a fourth tile aligned plane-to-plane with the third tile in the second plane,  
10 the third tile including a third collimator array disposed adjacent to a third beam steering  
11 array, and the fourth tile including a fourth collimator array disposed adjacent to the  
12 fourth beam steering array;  
13           coupling the first optical switching array to the second optical switching array,

14 whereby a maximum deflection angle of the three-dimensional optical cross-connect  
15 switch is less than or equal to the array maximum deflection angle; and  
16 directing the light signal into the first collimator array, whereby the light signal  
17 propagates toward the second plane.

1 48. The method of claim 48, wherein the second beam steering array reflects the  
2 light signal toward the first plane.

1 49. The method of claim 49, wherein the first beam steering array directs the light  
2 signal to an output port via the second collimator array.

1 50. The method of claim 49, wherein the first beam steering array directs the light  
2 signal to an output port via the fourth collimator array.

1 51. The method of claim 48, wherein the fourth beam steering array reflects the light  
2 signal toward the first plane.

1 52. The method of claim 52, wherein the first beam steering array directs the light  
2 signal to an output port via the second collimator array.

1 53. The method of claim 52, wherein the first beam steering array directs the light  
2 signal to an output port via the fourth collimator array.